

SPECIFICATION

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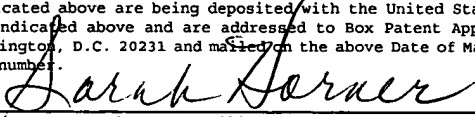
UNITED STATES PATENT APPLICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that I, Roger N. Wurtele a citizen of the United States of America, residing in the State of Texas, have invented new and useful improvements in a

AUXILIARY POWER UNIT FOR A DIESEL POWERED TRANSPORT VEHICLE

of which the following is a specification:

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BACKGROUND OF THE INVENTION

1. Cross Reference to Related Applications:

This application claims priority from earlier filed provisional application serial number 60/427,748, filed November 21, 2002, and entitled "Environmental Power System for Long Haul Trucks."

2. Field of the Invention:

The present invention generally relates to auxiliary power units and, more particularly, to auxiliary power units for use on transport vehicles powered by internal combustion engines to provide electrical power during periods when the transport vehicle's main engine must be shut off.

3. Description of the Prior Art:

Approximately one-half million diesel-powered trucks provide long-haul transport of goods throughout the United States. A common practice among truckers is to leave the diesel engines that power these trucks running - i.e., idling - during overnight stops. This practice occurs for a number of reasons, such as (1) to keep the cab and/or the sleeper compartment warm or cool; (2) to keep the diesel fuel warm during the winter months; (3) to keep the engine warm to avoid cold starting problems; (4) to mask other noises; (5) to enable use of various electrical devices in the truck cab, and the like. Idling these large engines burns significant amounts of fuel, far in excess of the amount needed to provide power for these benefits to the drivers. Such diesel fuel consumption needlessly consumes a non-renewable energy resource, burdens the costs of shipping goods with unnecessary expense, and results in significant amounts of air and noise pollution. Idling the engines of these transport vehicles for substantial periods of time also violate various federal, state and local laws and regulations. In addition to the costs of the wasted fuel and the environmental impacts of overnight idling are the higher maintenance costs due the excess wear that results from running the engines for

1 uses other than pulling a loaded trailer and increased health costs to treat illnesses caused by the
2 emissions from the engines.

3
4 A number of solutions to the idling problem have been developed and are currently in use.
5 These conventional systems generally employ an auxiliary power unit (APU) that runs on diesel fuel
6 and drives an electric alternator or generator to supply operating voltages for heating and cooling the
7 cab and/or sleeper compartment ("cabin") or recharging the truck battery. However, each of these
8 conventional systems has one or more of the following disadvantages: (1) the engine of the APU is
9 water cooled and must be tied into the radiator system of the truck or be provided with its own
10 radiator, hoses, water pump, etc.; (2) the engine of the APU drives the alternator or generator via a
11 belt drive, which is associated with reduced efficiency, reliability, and additional maintenance costs;
12 (3) the APU mechanically drives the A/C compressor for an auxiliary cooling system located in the
13 cabin of the truck; (4) the alternator or generator in the APU requires an inverter or converter to
14 provide a second output voltage in addition to the one it produces; (5) the APU requires extensive
15 integration into the truck fuel, cooling, exhaust and electrical systems, which increases the cost of
16 installing and maintaining the APU and reduces the reliability of the combined systems; (6) the
17 integration of the APU into the truck systems increases the mechanical complexity thereof resulting
18 in reduced reliability; and (7) the APU itself tends to be heavier and less efficient than it could be
19 using modern technology.

20
21 As an illustration, conventional auxiliary power units are typically liquid cooled and require
22 a radiator, a water pump, hoses, thermostat, etc., along with the mechanical structure to support
23 them. Conventional auxiliary power units also use some form of adapter that employs a belt, chain,
24 clutch or gear set to couple the engine to the generator, which adds weight, mechanical complexity
25 and additional maintenance requirements. Further, conventional auxiliary power units typically
26 require a converter circuit to produce a DC voltage from the generated AC voltage output or an
27 inverter circuit to produce an AC voltage from the generated DC voltage output. In either case, the
28 additional circuitry adds weight, complexity, maintenance requirements and cost, all without
29 improving the conversion efficiency of the auxiliary power unit. Efficiency is reduced in any of these

1 conventional auxiliary power units because the motive power supplied by the engine must be large
2 enough to overcome the extra losses associated with the more complex conventional auxiliary power
3 units.

4
5 What is needed is an efficient, compact APU of minimal complexity that overcomes the above
6 disadvantages, is easily integrated into an existing installation with an auxiliary heating and cooling
7 unit, and directly and efficiently provides both AC and DC electrical power for the cabin and for
8 battery recharging at minimum cost.

SUMMARY OF THE INVENTION

Accordingly, there is disclosed a high efficiency auxiliary power unit (APU) for a transport vehicle powered by an internal combustion engine. The APU comprises an air-cooled engine that uses the fuel supply and the engine exhaust system of the transport vehicle and has an integral, forced-air cooling system. An air-cooled, brushless generator, having an integral, forced-air cooling system and directly coupled to an output shaft of the air-cooled engine, provides simultaneous high voltage AC and low voltage DC outputs without using an inverter or a converter. An enclosure surrounds the air-cooled engine and the air-cooled brushless generator and provides protection and mechanical support. A system of first and second air ducts within the enclosure separately conveys cooling air into and through the air-cooled engine and the brushless generator respectively. The cooling air, drawn into the first and second air ducts by respective direct drive fan devices integrated in the air-cooled engine and in the brushless generator, exits from the enclosure through first and second air outlets.

In another embodiment, there is disclosed a system comprising a compact, AC operated auxiliary heating and air conditioning unit operable in the cab of a transport vehicle powered by an internal combustion engine and an auxiliary power unit (APU) having an air-cooled engine directly coupled to a brushless generator providing simultaneously a high voltage AC output and a low voltage DC output. The APU is operable, when coupled to a fuel supply, exhaust and electrical system of the transport vehicle, to supply the AC voltage to the auxiliary heating and air conditioning unit and to at least one AC branch circuit in the cabin of the transport vehicle, and to supply the DC voltage to the electrical system of the transport vehicle. Control means coupleable with the APU and the auxiliary heating and air conditioning unit controls the distribution of the high voltage AC output and the low voltage DC output of the APU and controls the operation of the auxiliary heating and air conditioning unit. Harness means couples the AC output to the auxiliary heating and air conditioning unit and to the at least one AC branch circuit, the DC output to the electrical system of the transport vehicle, and the control means to the auxiliary heating and air conditioning unit and to the APU.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an isometric view, partially cutaway, of the front, left corner of one embodiment of an auxiliary power unit (APU) according to the present invention, showing the arrangement of internal components and the paths of cooling air flow through the duct systems;

Figure 2 illustrates an isometric view of the rear, left corner of the embodiment of the auxiliary power unit (APU) shown in Fig. 1;

Figure 3 illustrates a simplified block diagram of air flow paths and of the electrical wiring of various components of the embodiment illustrated in Figures 1 and 2 ;

Figure 4 illustrates a pictorial view of the components of a system application in a transport vehicle including a heating and air conditioning system employing the APU according to the present invention;

Figure 5A illustrates a pictorial view of the rear of a truck tractor having an APU according to the present invention installed between the frame rails of the truck; and

Figure 5B illustrates a pictorial view of the right side of a truck tractor having an APU according to the present invention installed on the side of a frame rail of the truck.

DETAILED DESCRIPTION OF THE INVENTION

In the following description the term transport vehicle is taken generally to mean a motorized vehicle, such as a truck, ship or airplane, usually driven by a driver or pilot and used for the shipment of goods over long distances. In the disclosed embodiment a transport vehicle is a long-haul, diesel powered truck. This type of vehicle often includes a sleeping compartment in the cabin (cab) of the truck tractor unit. This cab is typically equipped with a heating and air conditioning unit, lighting, electrical outlets and small appliances, all of which are powered by an electric generator driven by the truck's engine or an auxiliary engine. Nevertheless, a transport vehicle could as easily be a boat equipped for the same type of shipping service, or even an aircraft configured for long distance hauling to remote areas, for example.

Referring to Fig. 1, there is illustrated an isometric view, partially cutaway, of the front, left corner of one embodiment of an auxiliary power unit (APU) 10 according to the present invention, from a slightly elevated perspective. Note that the left end of the APU 10 is facing to the right in Fig. 1. The APU 10 is enclosed in an enclosure 12 that includes a hinged cover 14, which pivots about hinge 16 as it is opened. The cover 14 opens to expose the front and upper portions of the interior to enable performing maintenance operations. The enclosure walls may be fabricated out of sheet metal, preferably hardened aluminum plate, such as Tread Brite - 3003, to minimize weight. The wall panels are secured to an 'angle iron' frame to form the rectangular-shaped box having dimensions of approximately 26" long x 18" wide x 19" high. The frame members (not shown) are located at each junction of adjacent wall panels of the enclosure 12. Mounting holes may be positioned in the frame members to support the APU 10 between the frame rails of a transport vehicle or to support the APU against one of the frame rails on the side of the transport vehicle.

The APU 10 of the present invention, because it is entirely air-cooled, because it requires no converter or inverter or voltage regulator circuitry and because it employs direct drive between the engine and generator, weighs only approximately 265 pounds. This may be compared with conventional auxiliary power units which are liquid cooled, generally require a converter or an

1 inverter to produce a second voltage output and typically require an adapter that employs a belt,
2 chain, clutch or gear set to couple the engine to the generator. The additional components required
3 in these conventional systems add weight, such that a complete conventional auxiliary power unit
4 often approaches or exceeds a weight of 400 pounds, significantly more than that of the auxiliary
5 power unit according to the present invention. The additional components required in the
6 conventional systems also add complexity, maintenance requirements and cost, all without improving
7 the efficiency. As mentioned previously, efficiency is reduced in any of these conventional auxiliary
8 power units because the motive power supplied by the engine must be large enough to overcome the
9 extra losses associated with the more complex and less efficient conventional auxiliary power units.

10
11 Returning now to Fig. 1, the enclosure 12, including the cover 14 is lined on the interior side
12 with a lining 18 on all interior surfaces except the bottom pan 20, and portions of the enclosure 12
13 where ducts within the enclosure 12 are vented to the exterior of the enclosure 12. The material used
14 for the lining 18 is provided to absorb sound energy generated within the enclosure 12. One material
15 that is suitable is a three-layer, ½ inch thick, mylar-faced sound insulation product called “GSI Sound
16 Stop Foam” available from Great Southern Insulation Corporation, Fort Lauderdale, FL 33335. This
17 product contains three layers of synthetic foam of varying densities to absorb sound energies
18 distributed across a range of frequencies. Other types of sound insulation may also be used. The
19 selection depends on such factors as the particular frequencies and intensities of the sound energy
20 generated within the enclosure 12 and the amounts of attenuation or absorption desired.

21
22 Continuing with Fig. 1, a pair of latches 22 secure the cover 14 when it is in a closed position.
23 An air-cooled engine 30 is mounted on the bottom pan 20, near one end of the enclosure 12,
24 supported by vibration-absorbing motor mounts 56. The air-cooled engine 30 includes a cylinder
25 head 32 and a crankcase 34. Air-cooled engine 30 is preferably a diesel engine so that it may use the
26 same fuel that most transport vehicles, into which the APU 10 of the present invention is installed,
27 currently use. However, air-cooled engine 30 is not limited to diesel fuel and may be selected to
28 operate on any viable fuel as long as a fuel supply is readily available. In the disclosed embodiment
29 the fuel supply is drawn from the transport vehicle’s fuel tank as will be described. The air-cooled

1 engine 30 in the disclosed embodiment is a Model 15 LD 350, 7.5 horsepower (Hp), single cylinder
2 diesel engine manufactured by Lombardini Motori of 42100 Reggio Emilia - Italia - ITALY and
3 available from Lombardini USA, Inc., 2150 Boggs Road, Duluth, GA 30096. Although a single
4 cylinder engine is suitable for the illustrative embodiment described herein, there is no necessary
5 limitation to a single cylinder. In some applications the engine of choice may have more than one
6 cylinder and still fall within the scope of the present invention. Further, while the typical internal
7 combustion engine employs a crankshaft from which the output is taken, other engine types, such as
8 a Wankel rotary engine that has an output shaft but not a crankshaft, may be well-suited to the APU
9 of the present disclosure.

10
11 A suitable alternative for the air-cooled engine 30 is a Model 15 LD 315, a 6.8 Hp version
12 of the same engine described hereinabove. Other power ratings may be used, the choice being
13 determined by the maximum amount of electrical power to be generated by the APU, which, in the
14 illustrated embodiment is approximately 5.0 KW. In most cases, the particular power ratings of the
15 engine and generator selected are a function of the particular application and the availability of
16 components having the specific ratings needed. In the APU of the present invention, the air-cooled
17 engine 30 develops the 7.5 Hp needed to drive the brushless generator to its full output of 5.0 Kw.
18 Thus, the approximate efficiency may be calculated as: $(5.0 \text{ Kw} / 0.746 \text{ Kw per Hp}) / (7.5 \text{ Hp}) \times 100$
19 $= 6.7 / 7.5 \times 100 = 89 \%$. As will be described, the key relationship between the power ratings of the
20 engine and the generator used in the APU is the efficiency of the unit. It will be appreciated by those
21 skilled in the art that a rotating machine configured as an electric generator needs only a motive force
22 to rotate the rotating element, e.g., the armature of the generator. Thus, any motive force capable
23 of the required torque, speed, etc. would be suitable.

24
25 Continuing with Fig. 1, the cylinder head 32 of the air-cooled engine 30 includes an array of
26 cooling fins disposed on the exterior of the cylinder head 32. These cooling fins, as is well-known,
27 increase the radiating surface area of the cylinder head 32 to better dissipate the heat produced by the
28 air-cooled engine 30. Disposed on the side of the crankcase 34 of the air-cooled engine 30 is an
29 injector pump 38. Injector pump 38 receives fuel from inlet fuel line 40 and controls the amount of

1 fuel injected into the air-cooled engine 30. The fuel line 40 delivers fuel from the fuel tank (See Fig.
2 4) of the transport vehicle carrying the APU 10 via a standpipe unit 121 installed in the fuel tank as
3 shown in Fig. 4. An exemplary standpipe unit used in the disclosed embodiment is a Model 903210A
4 manufactured by Webasto, a standard, off-the-shelf item. A return fuel line 42 connects a bypass
5 connection of the injector pump 38 back to a standpipe unit 123 installed in the fuel tank.
6

7 The air-cooled engine 30 includes a flywheel 44 configured as a fan. The flywheel fan 44
8 includes a series of radially-disposed vanes shaped to draw outside air inward toward the flywheel
9 through an opening as the flywheel fan 44 rotates when the engine 30 is running. The opening is
10 generally round, in a housing that surrounds the flywheel fan 44. The air drawn inward by the vanes
11 on the flywheel fan 44 is forced through an internal duct system alongside the engine, and closely past
12 the cooling fins 36, as will be described. The air-cooled engine 30 also includes an exhaust pipe 46,
13 which couples an exhaust port (not shown) on the cylinder head 32 of the air-cooled engine 30 to an
14 exhaust outlet 48 in a wall of the enclosure 12. In the disclosed embodiment of Fig. 1, the exhaust
15 outlet 48 is on a rear wall of the enclosure 12, for coupling to the exhaust system of the transport
16 vehicle as will be described. In the illustrated embodiment, the exhaust pipe is a flexible metal tubing.
17 In some applications, the exhaust pipe may be insulated against the escape of heat or excess sound
18 from the engine exhaust. An air intake pipe 50 coupled to an air intake port 52 on the air-cooled
19 engine 30 is provided for conducting outside air for combustion into the air-cooled engine 30. The
20 air intake pipe 50 typically passes through an air cleaner filter, which is not shown for clarity
21 purposes. An air cleaner disposed in the air intake of an internal combustion engine is well-known
22 to persons skilled in the art.
23

24 Continuing with Fig. 1, an air-cooled, brushless generator 60 is shown directly coupled to the
25 air-cooled engine 30. In the illustrated embodiment the crankshaft of the air-cooled engine 30 and
26 the armature shaft of the brushless generator 60 are directly coupled together such that both shafts
27 are aligned along the same axis. The coupling includes no belt, chain, clutch, or gear set. The
28 advantages of this configuration are compactness, no slippage in the drive mechanism, quieter
29 operation, efficiency, reliability and lower maintenance. However, it will be appreciated that, in some

1 applications, it is possible for the engine 30 and generator 60 to share a common housing. For
2 example, in technology currently in use in automotive applications a hybrid internal combustion
3 engine and electric motor assembly shares a common block, frame or housing. Thus, there is no
4 reason such a hybrid engine/generator architecture would not also be suitable for the APU of the
5 present disclosure.

6
7 The air-cooled brushless generator 60 selected for the APU of the present invention is chosen
8 because of its high efficiency and the capability of providing both high voltage AC and low voltage
9 DC outputs simultaneously and directly without requiring any converter or inverter or voltage
10 regulator circuits, either internally or externally to the generator. This design has the advantages of
11 simplicity, reliability, efficiency, light weight and low maintenance. The air-cooled brushless
12 generator shown in the illustrative embodiment is a 5.0 Kilowatt (KW) unit supplied by BMZ
13 Generators, Inc., 412 N. Federal Highway, Pompano Beach, FL 33062. The AC output is rated at
14 120 VAC @ 40 Amperes and the DC output is rated at 12 VDC @ 50 Amperes. A variety of other
15 output ratings are available as well as AC outputs having different voltages, single phase or multi-
16 phase, or a choice of 50 Hz or 60 Hz, or in combination with DC voltages at various levels.

17
18 The brushless generator 60 is supplied in a cylindrical housing with an air chamber or plenum
19 at each end of the generator 60. An exit fan 62, within an exit plenum 64 at the driven end of the
20 armature shaft next to the air-cooled engine 30, exhausts air warmed within the brushless generator
21 60, through a series of slots in the sides of the exit plenum 64. The air from the front-oriented side
22 of the exit plenum 64 then travels through a forward air duct 54 and an oil cooler 97 to exit to the
23 outside of the enclosure 12. The air from the rear-oriented side of the exit plenum 64 then travels
24 through a corresponding air duct (shown in Fig. 2 and to be described) to exit to the outside of the
25 enclosure. The exit fan 62 draws cooler outside air into the brushless generator 60 through an inlet
26 air duct 80. The cooler inlet air is directed through the brushless generator 60 where it absorbs heat
27 produced in the generator and conveys it toward the exit fan 62 located in the exit plenum 64.

Continuing with Fig.1, mounted on an upper corner of the entry plenum 68 is a generator output connector 70. Output connector 70 connects wiring to conduct the AC and DC output voltages from the generator output to a terminal on the rear side of the enclosure 12 (See Fig. 2). The wiring includes a pair of wires 72 supplying the AC voltage to a connector assembly on the rear panel and a pair of wires 74, 76 to supply the positive and negative respective polarities of the DC output voltage to corresponding terminals on the rear panel.

The enclosure 12, described hereinabove, though it resembles a simple box, presented a challenge in the design of the APU of the present disclosure because it must serve a number of purposes. In addition to providing protection from the weather and road debris and moisture, and providing convenient means for mechanical support on the transport vehicle, the enclosure 12 is relied upon to contain the sound generated within the enclosure by the air-cooled engine and the air-cooled, brushless generator. The sound is partly contained by the enclosure walls and partly absorbed by the sound insulation that lines the interior of the enclosure 12. Efforts, including experimentation, to solve the remaining problem, of removing the heat from within the enclosure 12, led to the configuration of the components of the APU shown in the illustrated embodiment. Accordingly, the enclosure 12 includes a system of air ducts to direct and control the flow of air into and through the air-cooled engine 30, the air-cooled, brushless generator 60 and the enclosure 12.

As shown in Fig. 1, an air inlet duct 80, having essentially a wide, low profile, rectangular cross-section, provides an enclosed passage for cool, outside air to enter the entry plenum 68 at the air inlet end of the brushless generator 60. The outside air 84, drawn by the exit fan 62, enters an air inlet vent (not shown) on the right side of the enclosure 12, travels downward through the duct 80 into the entry plenum 68. The air travels through the generator housing, picking up heat radiated by the internal structures of the brushless generator 60 and is drawn out through the vents in the sides of the exit plenum 64. The warmed air from the brushless generator 60 is forced away from the exit plenum 64, by the blades of the exit fan 62 within the plenum 64, and through the forward air duct 54 and oil cooler 98 and the rearward air outlet duct (See reference number 100 in Fig. 2) to the outside of the enclosure 12. This generator duct system thus removes heat produced by the brushless

1 generator 60, confines it to the duct system and prevents it from contributing to the build-up of heat
2 within the enclosure 12. To enhance the heat-confining capability of the generator duct system, the
3 ducts 80, 54, and 100 may be covered with thermal insulating material.

4
5 Also shown in Fig. 1 is an air inlet duct 86, having essentially a wide, low profile, rectangular
6 cross-section that provides an enclosed passage for cool, outside air to enter the housing containing
7 the flywheel fan 44 at the air inlet end of the air-cooled engine 30. The outside air 88 enters an air
8 inlet vent (See Fig. 1) on the left side of the enclosure 12, travels downward through the duct 86 into
9 the flywheel housing. There, the blades of the flywheel fan 44 gather the air as the flywheel fan 44
10 rotates, drawing the inlet air into the flywheel housing of the air-cooled engine 30. The air travels
11 through the engine structure around the cylinder head 32 and past the cylinder head cooling fins 36,
12 picking up heat radiated therefrom and is forced into an engine outlet duct 90, through which it
13 travels to an engine air outlet vent 92. In the illustrated embodiment of the APU 10 the engine air
14 outlet vent 92 is located on a rear panel of the enclosure 12 as shown in Fig. 2. In some applications,
15 it may be advantageous to install an exhaust fan (not shown), which may be thermostatically
16 controlled, in the engine air outlet vent 92 to pull more air through the engine air duct system under
17 heavy loads during periods of very high outside temperatures. The warmed air from the air-cooled
18 engine 30 is forced through the engine by the blades of the flywheel fan 44 within the flywheel
19 housing of the air-cooled engine 30, and through the engine air outlet duct 92 to the outside of the
20 enclosure 12. This engine duct system thus removes heat produced by the air-cooled engine 30,
21 confines it to the duct system and prevents it from contributing to the build-up of heat within the
22 enclosure 12. To enhance the heat-confining capability of the engine duct system, the ducts 86 and
23 90 may be covered with thermal insulating material.

24
25 Continuing with Fig. 1, an exhaust fan 98 is shown installed on a wall panel of the enclosure
26 12. Exhaust fan 98 is provided to remove residual hot air from the enclosure 12. Air inlet vents (not
27 shown) may be strategically placed in or near the floor or bottom pan 20 of the enclosure 12 to
28 facilitate air flow produced by the exhaust fan 98. Exhaust fan 98 may also be thermostatically
29 controlled or controlled by a central control system (not shown) located, for example, in the cab of

1 the transport vehicle. The Exhaust fan 98 may be AC or DC powered, with the electric current
2 provided by exhaust fan wires 99. The selection of the fan specification is based on the amount of
3 air, in cubic feet per minute (CFM), that must be moved through the respective duct system to
4 maintain temperatures within acceptable ranges for the particular device involved. Very often the
5 correct specification is determined after laboratory and field testing under actual conditions.
6 Heretofore, field tests of the APU disclosed herein on several long-haul trucks have demonstrated
7 the feasibility of the design described herein.

8
9 Referring to Fig. 2, many of the structures to be identified in Fig. 2 are the same as - and bear
10 the same reference numbers as - the structures shown and described in Fig. 1. In Fig. 2 there is
11 illustrated an isometric view of the rear, left corner of the embodiment of the auxiliary power unit
12 (APU) 10 shown in Fig. 1, showing internal components in phantom lines and the components of the
13 rear wall 21 of the enclosure 12. The enclosure 12 is shown with the cover 14 in a closed position.
14 The cover 14 is attached to the enclosure 12 along a hinge 16. Visible within the enclosure 12 are
15 the air-cooled engine 30, having a crankcase 34 and cylinder head cooling fins 36, mounted on motor
16 mounts 56 on the bottom pan 20. The engine exhaust pipe 46 is shown, as is the exhaust pipe
17 coupling 48 mounted on the rear wall 21 of the enclosure 12. The exit plenum 64 and the entry
18 plenum 68 for the generator 60 are shown, as are the generator air inlet duct 80 and the rearward air
19 outlet duct 100 coupled to a louvered generator air outlet vent 102. Further, there is shown in Fig.
20 2 the engine air inlet duct 86, which conveys outside air 88 that enters through the louvered panel 96
21 toward the air-cooled engine flywheel fan 44 as previously described. The warmed air 94 from the
22 air-cooled engine 30, forced through the engine by the blades of the flywheel fan 44 within the
23 flywheel housing of the air-cooled engine 30, is forced through the engine air outlet duct 90 to vent
24 at the air outlet 92 to the outside of the enclosure 12. The fan 98, for venting residual warm air from
25 the enclosure 12, is shown mounted in the upper, right portion of the rear wall 21 of the enclosure
26 12.

27
28 Continuing with Fig. 2, various connections of lines, tubes and wires that communicate with
29 the APU 10 of the present disclosure are shown mounted on the rear wall 21 of the enclosure 12.

Beginning at the lower left corner of the rear wall of the enclosure 12 in the figure, a positive terminal 104 and a negative terminal 106 for coupling the DC voltage output via respective positive lead 108 and negative lead 110 from the APU to the electrical system of the transport vehicle, generally at the battery, are shown. See, e.g., Fig. 4. Next to the negative terminal 106 is an AC terminal 112 coupled to AC leads 114. The AC leads 114, which supply power to the cabin of the transport vehicle, are routed to a control box in the cabin of the transport vehicle as will be described hereinbelow during the description of Fig. 4. At the lower right corner of the APU shown in Fig. 2 is a control terminal 124 for coupling a control cable 126 between the APU 10 and the cabin of the transport vehicle. To the left of the control terminal 124 are a pair of fuel line fittings. Inlet fuel fitting 116 receives fuel from the fuel tank of the transport vehicle via a fuel line 120 connected to a standpipe unit installed in the fuel tank. Outlet or return fuel fitting 118 returns bypassed fuel to the fuel tank of the transport vehicle via a fuel line 122 and a standpipe 123. Further details of the lines, tubes and wires that communicate between the APU 10 and the cabin of the transport vehicle or the electrical or exhaust systems of the transport vehicle will be described hereinbelow.

Referring to Fig. 3, there is illustrated a simplified block diagram of air flow paths and of the electrical wiring of the various components of the embodiment illustrated in Figures 1 and 2. An outline of a plan view of the auxiliary power unit 10 encloses outlines of the air-cooled engine 30 coupled to the brushless generator 60, the oil cooler 97 and the exhaust fan 98. The air-cooled engine 30 includes the cylinder head cooling fins 36 and the flywheel fan 44 described previously. The brushless generator 60 includes an air exit fan 62 and an output connector 70, also described previously. The paths representing the flow of outside air 84 into the brushless generator 60 and outside air 88 into the air-cooled engine 30 are shown as solid arrows pointing inward toward the air entry plenum 68 and the flywheel fan 44 respectively. Air outlet from the brushless generator 60 follows the dashed line paths leading away from the air exit fan 62, with one path passing through the oil cooler 97. The air outlet path 94 from the air-cooled engine 30, after passing through the cylinder head cooling fins 36, follows the solid arrows 94 en route to exiting the enclosure of the APU 10. A combustion air intake path, which enters with the incoming outside air 84, diverges along a

1 separate, dashed line path toward the air-cooled engine. As explained previously, the combustion air
2 flows through an air intake pipe 50 to the air-cooled engine air intake port 52.

3
4 Continuing with Fig. 3, wire leads from the output connector 70 include exhaust fan wires 99,
5 the output lead to positive DC output terminal 104, the output lead to negative output terminal 106
6 and the output leads to the AC output terminal 112. Fuel lines are shown in Fig. 3, including an inlet
7 line from the fuel inlet fitting 116 and a return line to the fuel return fitting 118. The air-cooled
8 engine exhaust pipe 46, represented by a dashed line, connects to the exhaust pipe coupling 48.
9 Wiring from a control panel, located inside the cabin of the transport vehicle as will be described,
10 connects to control terminal 124. From the control terminal 124, wiring connects the control terminal
11 124 to a control unit 128. Control unit 128, attached to the air-cooled engine 30, or coupled to it
12 by a short cable 129, may be used to facilitate preheating, starting, and running the air-cooled engine
13 30 during operation of the APU 10 of the present invention.

14
15 Referring to Fig. 4, there is illustrated a pictorial view of the components of a system
16 application in a diesel powered transport vehicle of a heating and air conditioning system employing
17 the APU 10 according to the present invention. Engine exhaust from the air-cooled engine 30 is
18 routed through an outside exhaust tubing 130 to an adapter tap 132 inserted in-line with an exhaust
19 stack 134 of the transport vehicle (not shown). In one embodiment, the adapter tap 132 is inserted
20 within the flex joint of an exhaust pipe 134. The outside exhaust tubing 130 may be a gas-tight
21 flexible metal tubing material, e.g., a corrugated stainless steel tubing, for ease of installation and the
22 capability to isolate harmonic vibrations traveling in either direction along the outside exhaust tubing
23 130. Other connections to the APU 10 include the storage battery 136 of the transport vehicle, which
24 is connected via a positive DC output lead 108 and a negative DC output lead 110 to the APU 10.
25 AC leads 114 connect the APU 10 to a distribution panel 172. The control cable 126 connects the
26 APU 10 to a control panel 150. Inlet fuel line 120 and return fuel line 122 connect the respective
27 fittings on the APU 10 with the fuel tank 138 of the transport vehicle via respective standpipe fittings
28 121, 123.

1 Inside the cabin of the transport vehicle, typically under the bunk bed or other convenient
2 location, is installed a self-contained, 110 volt heating and air conditioning (H-A/C) unit 140. A
3 suitable H-A/C unit 140 is Part No. 090-00456 available from SCS/Frigette Corporation, Fort Worth,
4 TX 76140. This unit provides 9,000 BTUs of air conditioning and approximately 1,500 watts of
5 electric heating. The H-A/C unit 140 includes several outlets such as air outlet 142 shown in Figure
6 4, for connecting to air vents (not shown) within the cabin of the transport vehicle and a return air
7 inlet 144. Also inside the cabin of the transport vehicle is a control panel 150 that includes a green
8 lamp 152 to indicate when the air-cooled engine 30 of the APU 10 is running and an orange lamp 154
9 to indicate when it is time to change the filter in the H-A/C unit 140. The control panel 150 further
10 includes an ON/OFF switch 156 for the engine ignition, a PREHEAT/START switch 158 for starting
11 the air-cooled engine 30, and an hour meter 160 to log the hours of operation. The control panel 150
12 is coupled to the APU 10 via control leads 126.

13
14 Another unit inside the cabin of the transport vehicle is a thermostat 162, connected to the
15 H-A/C unit 140 via wires 172, for controlling the operation of the H-A/C unit 140. The thermostat
16 162, which is a standard item typically shipped with the H-A/C unit 140, includes a display to indicate
17 the temperature of the cabin and a preset temperature setting. The thermostat may also include
18 switches 166, 168 for adjusting the temperature setting up or down, respectively. A switch 170
19 provides ON/OFF control of the H-A/C unit 140. The cabin may also be equipped with first and
20 second AC outlet boxes 146, 148.

21
22 The APU 10, the H-A/C unit 140 and the control panel 150 are electrically connected
23 together via a harness assembly 174 shown within the dashed line in Fig. 4. The harness assembly
24 174 may include all wiring routed to an AC distribution panel 176 and the control lines between the
25 APU 10 and the control panel 150. The harness assembly 174 may include various connectors (not
26 shown) and wiring installation accessories (not shown) for adapting to the particular installation. The
27 AC distribution panel 176 includes circuit breakers for controlling delivery of AC power to the H-A/C
28 unit 140 via wires 184, to the AC outlet boxes 146, 148 via wires 180, 182 respectively and to an
29 auxiliary circuit to other devices on the transport vehicle, such as an engine preheater (not shown)

1 for example. The switches in the AC distribution panel may include, or be incorporated into, circuit
2 breakers with ratings suitable for the intended electrical loads.

3
4 Referring to Fig. 5A, there is illustrated a pictorial view of the rear of a truck tractor 190
5 having a cabin 192 and an APU 10 according to the present invention installed between the frame
6 rails 194, 196 of the truck 190. The APU 10 is supported by angle brackets 198, 200 bolted to the
7 enclosure 12 of the APU 10 and the frame rails 194, 196 respectively. In a preferred embodiment,
8 the angle brackets 198, 200 are isolated from the frame rails 194, 196 by vibration-absorbing pads
9 195, 197. A suitable material for the vibration-absorbing pads is neoprene rubber, one-half inch thick.
10 In the illustrative embodiment, the vibration-absorbing pads are approximately 2-1/2 inches wide and
11 22 inches long. However, the thickness of the neoprene pads, and the durometer thereof may be
12 predetermined according to the results of experiment and characteristics of the particular application.
13 In another embodiment, the APU of the present invention may be supported on the transport vehicle
14 using a clamping assembly. A clamping mounting assembly enables the mounting and installation of
15 the APU on the transport vehicle without requiring drilling or welding operations.

16
17 In one example of the clamping assembly, L-shaped angle brackets 198, 200, approximately
18 22 inches long and bolted to the enclosure 12 of the APU 10 along the vertical side of the angle
19 brackets 98, 200, extend approximately two inches fore and aft beyond the front and rear walls, on
20 each side of the enclosure 12. The horizontal sides of the L-shaped angle brackets 198, 200 which
21 extend laterally away from the sides of the enclosure 12, rest on the top of the frame rails 194, 196.
22 Inverted U-bolts, and spacer bars (not shown) drilled to fit over the threaded ends of the U-bolts, may
23 be used to clamp the ends of the L-shaped angle brackets 198, 200 to the frames rails 194, 196
24 respectively. To absorb vibration, neoprene pads 195, 197 may be installed between the L-shaped
25 angle brackets 198, 200 and the upper side of the frame rails 194, 196 and also between the spacer
26 bars (not shown) and the lower side of the frame rails 194, 196. The APU 10 may thus be supported
27 between the frame rails 194, 196 as shown in Figure 5A.

1 Also shown in Fig. 5A, in phantom lines, is the connection of the exhaust pipe 130 from the
2 APU 10 to the exhaust pipe 134 of the truck 190 using the adapter 132 as previously described. In
3 Fig. 5B, there is illustrated a pictorial view of the right side of a truck tractor as in Fig. 5A having an
4 APU 10 according to the present invention installed on the side of the truck 192 and supported by
5 a support bracket 202 attached to the frame 204 of the truck 192. The support bracket 202 may be
6 isolated from the frame 204 by vibration-absorbing pads installed therebetween or by vibration-
7 absorbing mounts attached to the bottom of the enclosure 12.

8
9 To summarize, there is disclosed hereinabove an auxiliary power unit (APU) for a transport
10 vehicle powered by an internal combustion engine. An enclosure houses and supports the APU on
11 the transport vehicle. An air-cooled engine within the enclosure directly drives an air-cooled,
12 brushless generator. The generator provides direct, simultaneous AC and DC voltage outputs
13 without requiring an inverter circuit or a converter circuit. Air duct systems within the enclosure
14 separately convey cooling air into, through and out of the air-cooled engine and generator. The
15 cooling air, drawn into the air duct systems by respective direct drive fan means integrated in the air-
16 cooled engine and generator, exits through respective air outlet ducts from the enclosure. In another
17 embodiment, a system is disclosed comprising a compact, AC operated auxiliary heating and air
18 conditioning unit operable in the cabin of a transport vehicle and powered by the APU described
19 above. The system may include control means coupled to the auxiliary heating and air conditioning
20 unit and the APU, and harness means for coupling the auxiliary heating and air conditioning unit, the
21 APU, and the control means together.

22
23 While the invention has been shown in only one of its forms, it is not thus limited but is
24 susceptible to various changes and modifications without departing from the spirit thereof. For
25 example, as discussed hereinabove, various types of air-cooled internal combustion engines or various
26 types of air-cooled generators may be used in the disclosed APU. Similarly, the air duct systems may
27 be modified in various ways, with or without fan-assisted air movement, to manage the air flow
28 through the engine and generator. The enclosure configuration may likewise be modified to
29 accommodate the modifications to the internal components and systems made to satisfy particular

1 applications. Persons skilled in the art will realize that various modifications may be made to the
2 location of wiring terminals, air inlets and outlets, covers or access panels, mounting structures, fuel
3 supply and exhaust connections, lines or conduits, as illustrative examples, yet remain within the
4 scope of the invention as claimed. Further, the choice of materials used in the enclosure and other
5 elements of the structure, for example, may be made without departing from the scope of the
6 invention as claimed.